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Aviation Fuels Quality Control

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Aviation Fuels Quality Control

by

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BACKGROUND

Many operations by Forest Service contract helicopters take place at locations away from airports which have routine fuel quality control. At these field locations, aircraft fuel is supplied from contractor fuel trucks. This results in added opportunity for the fuel to become contaminated by free water or solid particulates. In the past, several accidents have been traced to fuel contamination. Although Forest Service contracts require fuel trucks to be equipped with three stage fuel filters, a method of testing the fuel to verify that the fuel filters are operating properly is needed.

TYPES OF FUEL CONTAMINATION

Mixing of Fuel Types

This is a common type of fuel contamination. Several varieties of fuels are used around most airports and care must be taken to assure that the wrong fuel is not used or that two fuel types are not mixed. An incorrect fuel can result in malfunctioning of the aircraft engine.

Free Water

Water is present in all fuel. It can be in the form of dissolved water or in the form of free water. If it is present in amounts below the saturation level of the fuel, it will be in the dissolved form and does not create a problem. In amounts above the saturation level of the fuel, the water occurs in the form of free water and can cause flameout, fuel tank corrosion, bacteria growth, and icing of the fuel system.

Solid Particulates

This includes dirt, rust, scale, and other foreign solids. They may cause flameouts, excessive wear of pumps, plugging of fuel filters, and malfunctioning of other fuel system control devices. They also provide nutrients for the growth of bacteria.

Bacteria

Bacteria usually occur in the presence of other contaminants such as water, solid particles, or surfactants. They contribute to clogging of fuel filters, fuel tank corrosion, and fuel gauge malfunctioning.

Surfactants

The word surfactant is a condensation of the words "surface active agent." It represents a group of chemicals which act as wetting agents similar to those found in soaps. Surfactants come from fuel additives, refinery treating processes, or naturally occurring materials in the fuel system. They become harmful at concentrations between ½ and 2 ppm by causing fuel filters to become ineffective. Solid particles and water droplets coated with a surfactant will pass through a fuel filter.

TOLERABLE LIMITS—FREE WATER

There is some ambiguity in the literature, and amongst manufacturers, as to the maximum permissible free water contamination limit allowable. Most manufacturers, when they give a limit, set the free water maximum specification at 30 ppm in the preferred fuel, which is almost always JP4 or JP5. For the "nonpreferred" fuels, no limit is usually given. Sikorsky, for the S61-N, sets a maximum limit of 40 ppm if a 3-cell system is used, and 60 ppm if a 2-cell system is used. These are per tank limits, i.e., when one tank is sampled, the free water cannot exceed that limit. Averaging across tanks is not permitted.

Many manufacturers (i.e., Hughes, Hiller, and for some helicopters, Bell) state only that the fuel must meet the requirements of MIL-T-5642, or ASTM D-1655. Neither of these standards contain a specification for free water or particulate contamination. However, a military standard, referenced in MIL-HDBK-200E, requires, for "into aircraft," 10-ppm maximum *and* a "filter separator" unless the fuel is to be dispersed to the Navy for which the requirement is 5 ppm. (The Navy's lower standard is due to the more deleterious effect of salt water on engines and fuel controls.)

It is apparent then, that fuel that contains less than 10-ppm free water is acceptable, and fuel that contains more than 30-ppm free water is unacceptable. The most serious potential problem with free water in the 10- to 30-ppm range is the possibility of freezing, and the resultant ice causing failure of the fuel control systems. Thus, for warm weather operations, the 30-ppm standard, the most stringent recommended by helicopter manufacturers, will adequately protect our helicopter operations. When freezing temperatures are likely to be encountered, an added margin of safety is had by adhering to the lower 10-ppm standard.

TOLERABLE LIMITS—PARTICULATE CONTAMINATION

No helicopter manufacturer specifies an acceptable limit for particulate contamination. All insist upon "clean and bright" fuel. Military and ASTM specifications are likewise mute on the point. However, MIL-HDBK-200E does set a "deterioration" limit of 1.0 mg/1 (2.0 for Naval aircraft).

Based on the information available, it would seem that a limit of 1.0 mg/1 could be applied to Forest Service aircraft servicing.

TESTS FOR FUEL CONTAMINATION

Contamination by free water and solid particles are the most common problems encountered by the Forest Service in its helicopter field operations. To determine the best method

of field testing for these contaminants, knowledgeable sources in the industry were consulted, including the Army Petroleum Laboratory at Fort Lee, Virginia; the Shell Oil Company of Houston, Texas; and Petroleum Equipment Distributors of Hayward, California.

It was determined that the following tests are used throughout the industry for testing for free water and solid particles. Each has varying sensitivity and equipment requirements. They are listed below in order of increasing sensitivity to contaminants:

Free Water	*Solid Particle*
1. White bucket test	1. Clean and bright test
2. Clean and bright test	2. White bucket test
3. Metrocator test	3. Mini-monitor test
4. Aqua-Glo test	

White Bucket Test

A sample of fuel is drawn into a bucket coated with white porcelain enamel and examined visually for evidence of solid particles or free water. The bucket may be swirled so that a vortex is created. Solid contaminants, if present, will tend to collect at the bottom beneath the vortex. To assist in the determination of whether any free water is present, a few drops of a liquid vegetable dye can sometimes be helpful to outline the free water in a sample.

The white bucket test can, if skillfully and conscientiously applied, detect particulate contamination in the 1- to 2-mg/1 range. To be visible to the naked eye as specks, the sediment particles must be larger than 40 microns in size. Any appreciable number of visible sediment particles in a sample indicates the fuel probably exceeds 2.0 mg/1 and further testing is necessary before the fuel is used to service an aircraft. Even with the most efficient filter separator and careful fuel handling, occasionally there will be visible sediment particles in fuel because a few are able to get through the filter. More often, sediment will be in the form of an extremely fine powder, rouge, or silt. In a sample of acceptably clean fuel, no sediment should be visible.

While the "clean and bright" test is a better test for the presence of free water, water suspended throughout the fuel sample will show in the white bucket test. Free water will settle out, but in JP4 and especially in JP5, it will settle very slowly. Any free water in the form of droplets on the bottom of the white bucket is cause for rejection of the fuel without further testing as described below.

Clean and Bright Test

This test is similar to the free water white bucket test. It has the advantage that it can detect smaller amounts of contamination, but is, according to some experts, less sensitive to solid particles. A clean, 1-quart clear glass jar similar to those used for canning foods is used. The jar is filled with a sample of fuel and then visually examined for contamination. If the fuel is free of solid particles, it will appear clear. If the fuel is acceptably free of water, it will appear bright with a fluorescent appearance and will not be cloudy or hazy.

The "clean and bright" test is a bit more than just swirling a quart of fuel around in a mason jar, as has sometimes been intimated. The jar must be scrupulously cleaned, first with tap water, then with distilled water, and finally with isopropyl alcohol, and must possess certain optical qualities to allow for an undistorted view of the fuel. Free water on the order of 30 ppm will create a definite haze or cloud in the fuel. Such a haze or cloud is cause for rejection until further testing can be accomplished. Also, it should be remembered that just allowing the fuel to sit for a day or two will often cause the free water to settle out, allowing the dry fuel to be decanted, or pumped off the top safely. It must be emphasized that no fuel with a free water concentration of more than 30 ppm should be used to service an aircraft.

Metrocator Test

This test kit (fig. 1) is manufactured by the Scott Manufacturing Company of Farmingdale, New York, and is capable of detecting free water with a precision of 5 ppm. A measured amount of fuel is added to a vial. Dye powder is added to the fuel and a filter paper disk is inserted into the vial cap. The vial is then capped and shaken vigorously for a minute or two until the dye powder is completely dissolved. The filter paper disc is then removed and the blue spotted pattern on the filter paper is compared to standard patterns to determine the free water concentration.

Aqua-Glo Test

This test kit (fig. 2) is manufactured by Gammon Technical Products of Manasquan, New Jersey. It measures the free water content of turbine fuel per ASTM Method D-3240. The kit can detect free water content with a precision of 1.5 ppm. It is important to distinguish between the threshold of the test and the accuracy, precision, and repeatability of the test method. While it is not necessary to detect water at a threshold as low as 1.5 ppm, it is necessary to accurately determine the water present. A measurement within 1.5 ppm is accurate, at the 30 ppm specification, within 5 percent. This is marginally acceptable. The test is performed in two steps. First, a measured sample of fuel is filtered through a paper pad that is treated with sodium fluorescein on its upstream surface. Second, the pad is compared under fluorescent light with a standard to determine the concentration of free water present.

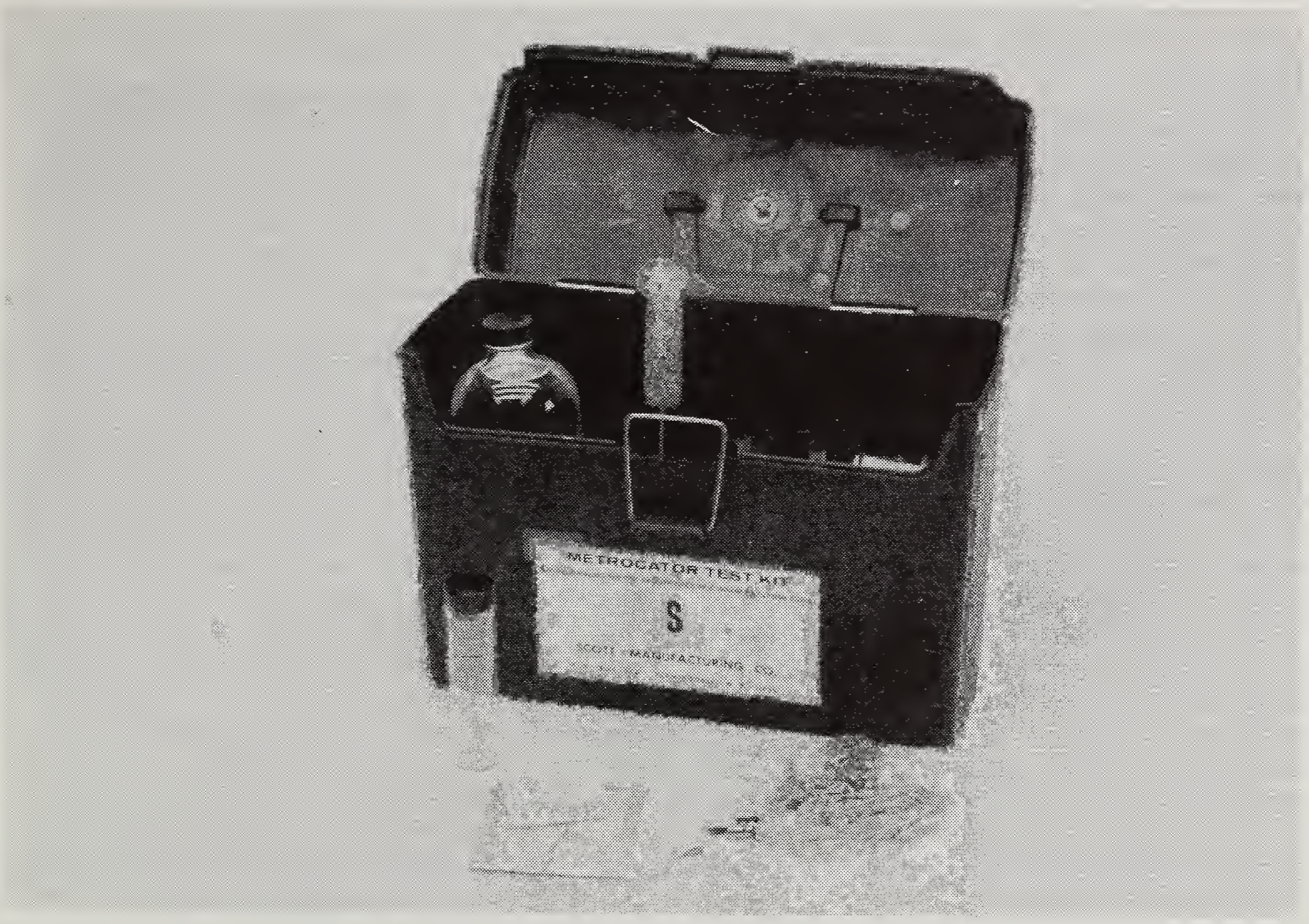

Figure 1. Metrocator Test Kit for free water contamination.

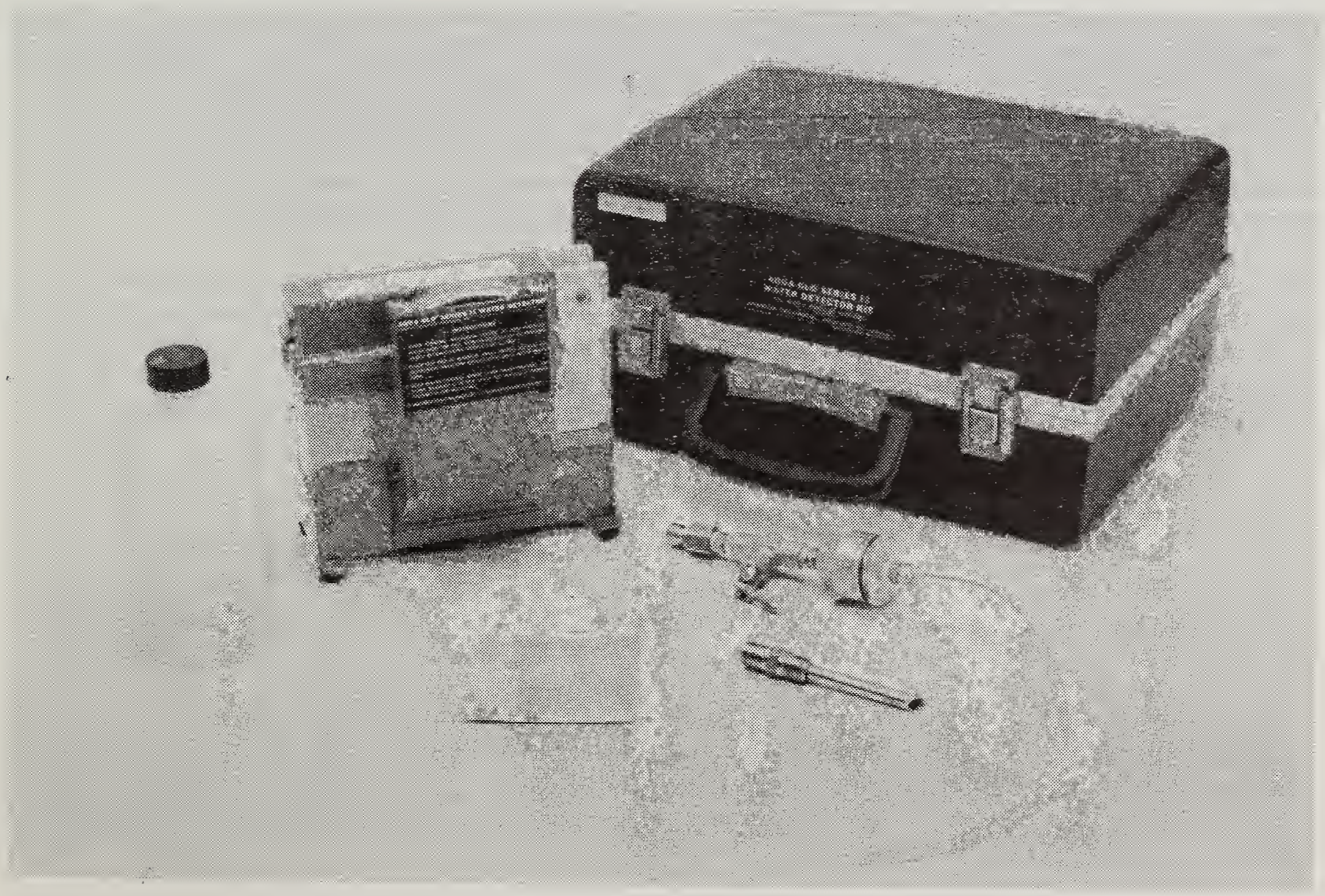

Figure 2. Aqua-Glo Test Kit for free water contamination.

Mini Monitor Test

The Mini Monitor test kit (fig. 3), also manufactured by Gammon Products, is designed for testing turbine fuel for solid particle contamination per ASTM Method D-2276. The test is conducted by passing a measured amount of fuel through a Millipore membrane that is housed in a plastic monitor. The concentration of solid particulate contamination is then determined by weighing the Millipore membrane or by comparing its color to a standard color chart.

Fuel Sampling

In order for a fuel contamination test to be valid, the fuel sample must be representative of the fuel being delivered to the aircraft. To accomplish this, the fuel should be removed from the circulating stream of fuel in the fuel system as close to the hose nozzle as possible. There are standard fuel probes with quick disconnect fittings for this purpose. These probes are permanent installations and should be located immediately on the output side of the three-stage filter required on fuel trucks. The probe inlet should be located at the center of the fuel stream and not at the sides or inside a fitting attached to the pipe where contaminates tend to concentrate. This method eliminates the additional fuel contamination which occurs when samples are taken with a bucket.

FIELD TESTS

A Metrocator kit and an Aqua-Glo kit to test for free water and a Mini Monitor kit to test for solid particulate contamination were purchased by San Dimas. These kits were used to test Jet A fuel from a fuel truck owned by Evergreen Helicopters which was located at the Dalton Station of the Angeles National Forest. The truck was equipped with a fuel sampling port located on the output side of the three-stage filter. The Aqua-Glo test took 15 minutes, the Mini Monitor test took 40 minutes and the Metrocator test took 10 minutes. No problems were encountered except that the dye in the Metrocator test did not completely dissolve. The major bottleneck encountered was the time required to run 5 gallons through the Mini Monitor filter.

We were unable to discover any acceptable tests that provided more accuracy and precision than the white bucket and "clean and bright" tests which did not take as much time to run as the Aqua-Glo and Mini Monitor tests. Indeed, the white bucket and "clean and bright" tests are the standard in the industry, and have been for some time. It is unlikely that tests of intermediate accuracy and precision could be developed without an extensive program of invention, development, verification, and correlation. If a batch of fuel passes both the white bucket and the "clean and bright" test, scrupulously administered, and if the required three-stage filter separator is properly functioning, it is unlikely that the fuel is contaminated. The more time consuming tests (Mini Monitor and Aqua-Glo) should probably be used if there is a suspicion of fuel contamination, as revealed by inspection of the filter system, or by the "short time" tests. A more fruitful avenue would seem to be a quality control inspection procedure for the required three-stage filter system. This could incorporate the standardized Aqua-Glo and Mini Monitor tests.

RECOMMENDATIONS

The white bucket and "clean and bright" tests should be administered to each batch of fuel used to service Forest Service helicopters. A procedure for monitoring the three-stage filter separator required on all fuel supplies should be developed, based on the Aqua-Glo kit for testing for the presence of free water and the Mini Monitor kit for testing for solid particulate contamination. Both kits are produced by Gammon Technical Products, Incorporated, and can be purchased together for $1,000. This equipment is the standard field test equipment used in the military and the petroleum industry. It allows tests to be conducted in a reproducible manner to ASTM specifications by personnel with a minimum of training.

In order to perform these tests, it is recommended that all fuel trucks under contract to the Forest Service be required to be equipped with a ¼-inch pipe size stainless steel fuel sampling probe and a quick disconnect fitting. This fuel probe should be located immediately on the output side of the truck's three-stage filter.

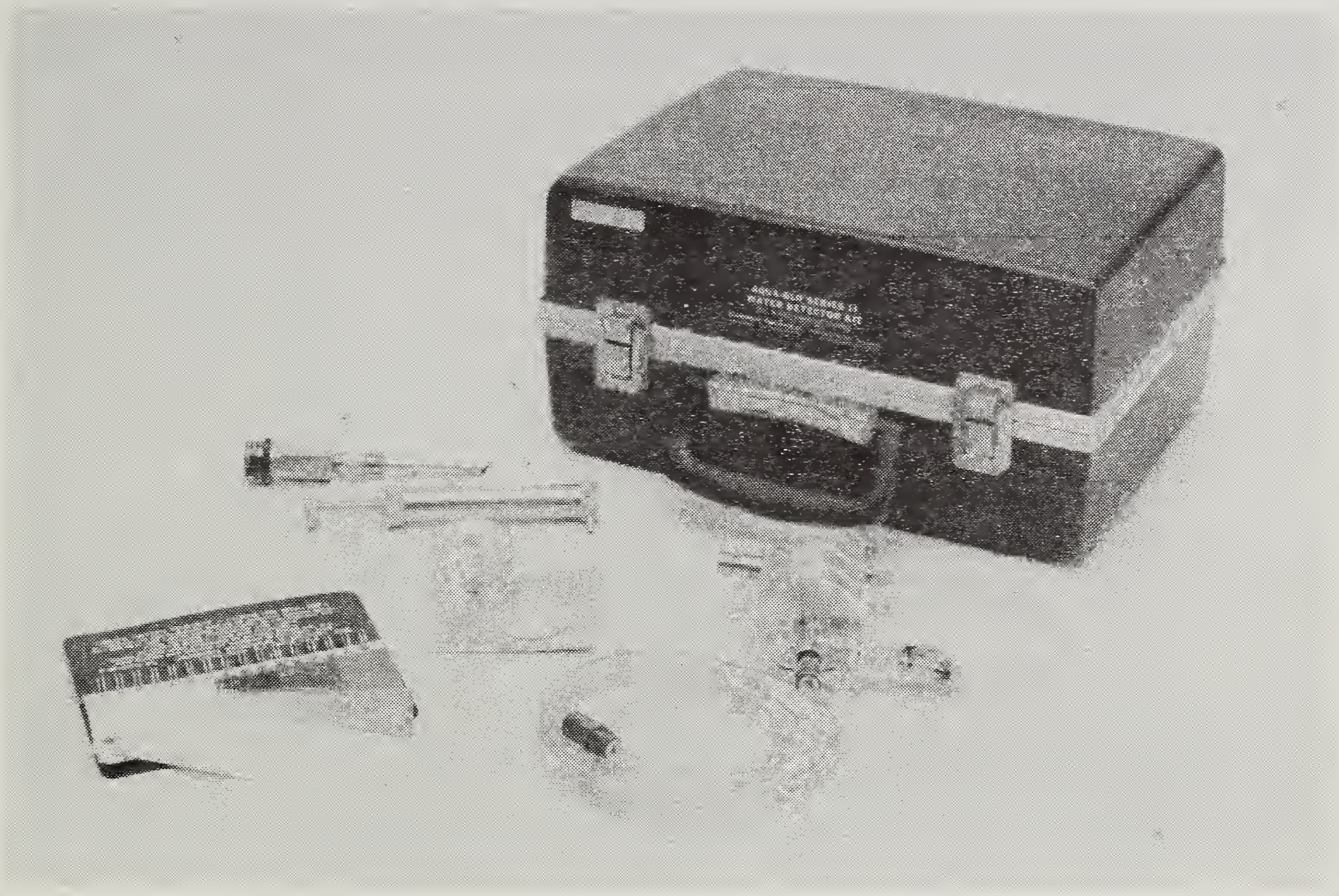

Figure 3. Mini Monitor test for solid particle contamination.